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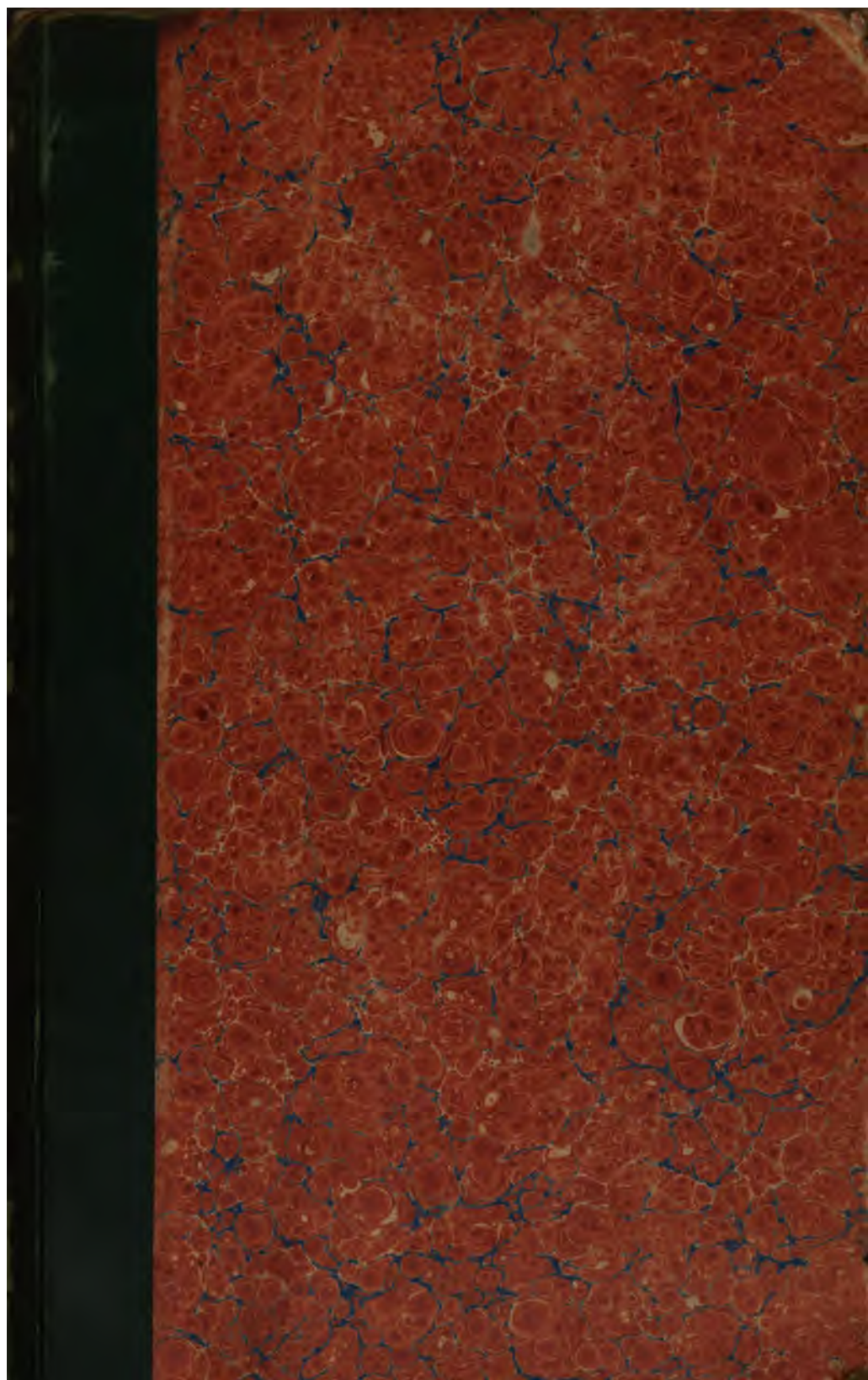
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Garnett Ball

R E M A R K S
ON THE
COMPARATIVE ADVANTAGES
O F
WHEEL CARRIAGE
OF DIFFERENT
Structure and Draught.

BY ROBERT ANSTICE.

PRICE HALF-A-CROWN.

126

R E M A R K S

O N T H E

C O M P A R A T I V E A D V A N T A G E S

O F

W H E E L C A R R I A G E S,

O F D I F F E R E N T

S T R U C T U R E

A N D

D R A U G H T.

I L L U S T R A T E D W I T H P L A T E S.

By *ROBERT ANSTICE.*

B R I D G E W A T E R ;

P R I N T E D F O R T H E A U T H O R , B Y S . S Y M E S ,

S O L D B Y R . B A L D W I N , I N P A T E R N O S T E R R O W
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A N D A L L O T H E R B O O K S E L L E R S .

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T O T H E
RIGHT WORSHIPFUL AND WORSHIPFUL
THE MASTER AND OFFICERS,
AND THE BRETHREN,
OF THE LODGE OF
LIBERTY AND SINCERITY

No. 369.

IN BRIDGEWATER, SOMERSET,
THIS SMALL TREATISE, THE FRUIT OF
LEISURE HOURS EMPLOYED AGREEABLY
TO THE INSTRUCTIONS CONVEYED IN
THE CHARGES OF OUR BENEVOLENT
INSTITUTION, IS INSCRIBED AS A
TESTIMONY OF AFFECTION, BY THEIR
ZEALOUS AND FAITHFUL BROTHER,

The A U T H O R.

ADVERTISEMENT.

THE theory contain'd in the following pages is the result of a variety of experiments, and of a careful investigation of facts on a subject generally interesting.

A doctrine published a few years since by another hand, with the profess'd generous intention, that it might be either confirmed or refuted by the experience of others, has occasioned the Author of this, to arrange it in it's present form; and as many of the premises in the work alluded to, are admitted, he has adopted some of the figures, to give such as may be readers of both, an opportunity of contrasting the deductions, and determining their judgment accordingly.

Bridgewater,
December, 1789.

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REMARKS

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R E M A R K S

O N

WHEEL CARRIAGES.

TO understand the general effects produced by the application of wheels to carriages, and the particular advantages of those of one construction compared to those of another, it is necessary to consider some principles pertaining to matter in general, but more particularly its motion, as far as relates to the subject.

SECTION

B



S E C T I O N I.

ABSOLUTE Motion is the passage of any body, from one place or situation to an other; as rest is the continuation of all it's parts, in the same points of actual and immovable space.

THAT relative motion which is material to our present enquiry, is derived either from an exertion of muscular power, or of that principle, the action of which when confined to bodies on the earth, we call attraction; when applied to the earth and any other body, it is called gravity.

As without the agency of these or other obvious causes, matter on the earth would be relatively

lately inactive, it has been supposed by some to possess a quality, disposing it to rest; ‡ but every power (however small,)
B 2
being

‡ This too general idea seems to arise, from a misunderstanding of the vis inertia attributed to matter by Sr. Isaac Newton, and other great writers on the subject; by which, they meant nothing in matter operating either towards rest or motion; but a passiveness to abide in that state in which it is placed by any agent; whereby, it alters not from that state, but in proportion to the quantity of power, which is exerted against it. Thus, should a body of any given weight or quantity of matter, moving with a certain velocity, strike another body at rest of the same weight, it would communicate half it's motion to that body, and they would move together with half the velocity of the first; but this proceeds from no principle in the body at rest to resist motion, it does not destroy in the other more than it receives from it; therefore no motion is lost, it is only divided, and the two after the division, have a power equal to that of the one before it with the whole velocity of motion. Indeed, when we consider that the least degree of motion in any body, however small, will communicate some degree of it to the largest in the universe, and that on the contrary none but an exactly equal degree of impetus can deprive a body of actual motion, and that immediately opposed to it; add to this, that since all matter within the reach of our observation, and by analogy we have reason to think that all in the universe is in actual and rapid motion, impress'd on it by it's great Creator, and co-existent with

being capable of acting on, and producing, (or under some circumstances destroying,) a proportionate motion in any independent body, how large soever it may be, no such disposition can exist, consequently, is of no estimation in any calculation whatever, either of the production or continuation of motion; for that being once communicated, will continue as long as the laws of nature exist, unless it be counteracted by some power, or retarded by being in contact with some matter at rest, or possess'd of a motion different from it's own, whereby a rubbing of parts or friction is produced; whole effects being very material to our purpose, and varying according to the circumstances attending the touching surfaces, we will consider them, in the following section.

with it, we may conclude, that if matter do not affect, it is yet more liable to motion than rest.

SECTION



S E C T I O N II.

FRICTION, or the quantity of motion destroyed by bodies sliding over, or against each other, is ever in a ratio, proportionate to the roughness of the touching surfaces ; the weight or pressure acting on them ; and the form and strength of the parts composing these roughnesses or inequalities ; which proportion is entirely dependent, on the different prevalence of either of those circumstances.

For, as the surfaces of all, even the highest polished bodies, have inequalities ; consequently, whenever two such are placed on, or against each other, and press'd together, those of one
must

must slide into, and in some degree fit those of the other; the variety of size and figure of whose parts being infinite, I will only delineate them of two sorts, in order not only to express and argue on the action of such as these two exactly describe, but also on that of all others, as they come the nearest to either of them.

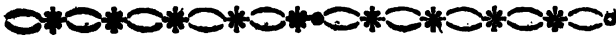
First, let us imagine the parts of two surfaces, which are to slide over each other, to be (when seen thro' a microscope,) as described, in the plate 1st. fig. 1st. in which A is the sliding body to be moved in the direction C, D, over the fixed body B; now it is evident that to effect this, the teeth which represent the inequalities of the surfaces, must be violently broken away; or (if they be too strong for that,) there must be a power applied, sufficient to raise the sliding body, so as for it's teeth to pass over those of the body fixed below it, by acting as inclined planes, (to be treated of in the next section;)

section ;) and in this case, the friction or resistance will be ever in proportion to the weight of the slider, and it's load ; without any regard to the length and breadth of the bearing surface : for, if one pound weight bore in this manner on one tooth, there would be a pound to be lifted over that tooth ; if on two, the weight would be divided between them, and there would be but half a pound to lift over each, and so on to any number ; but if we alter the case, and make the teeth or indentures of such a shape, that they cannot possibly act as inclined planes, be they never so strong ; then would the calculation of the degree of friction, by the weight or pressure of the slider, be very fallacious.

Let fig. 2d. plate 1st. represent such surfaces, and it will be clear, that instead of depending on the weight or pressure only, it will be in proportion to the number and strength of the teeth so locked together ; or in other words, on the
length

length and breadth of the rubbing surfaces.—For then will the weight of the slider have little or no effect, in breaking the teeth or hindering it's being done, by the power applied in the direction C D ; but if one tooth be to be broken, it will require a certain power to do it, if two, double that power, and so on ; hence, as it is impossible, to ascertain exactly the form of all the little prominences on rubbing surfaces, or nearest to which of those figures they come in general ; so is it impossible, to give any fixed rule, to determine the proportionate friction of different extended surfaces, under the same pressure ; but as experience has shewn that two bricks, or any two such bodies are almost as easily drawn on a table, when placed flat, and side by side, as when lain on each other ; it is evident, that such locking of parts seldom occurs, and when it does, is perhaps soon broken down, and brought nearer to the figure first described. All I insist on is, that it occurs partially

partially, for without it the wearing observed to take place by friction, could never happen.



S E C T I O N III.

FROM what has been said in the preceding sections, it is evident, that if a body, such as a sledge be placed on a plane perpendicular to the line of the earth's attraction, or gravity acting on it, it will remain at rest ; being hindered from receiving motion from that power of attraction, by the plane which supports it at right angles, or in a direction immediately opposed to that attraction. But, as by motion being communicated to it in the direction of the plane, it would not be in the least removed from the object of it's attraction, it would therefore,

C

(if

(if there were no friction,) be put in motion by the least possible power.

If the plane on which the sledge is laid, be inclined towards the line of attraction, then will it slide, (as it thereby yields to the impulse of it's gravity,) in proportion to the inclination of the plane; and consequently, that sliding can only be effectually counteracted, by a power opposed to it in the same proportion; that is, at whatever angle the plane be, the resisting power acting in a line parallel to the plane, must bear the same proportion to the weight, as the perpendicular descent of any given part of the plane, bears to the length of that part of the plane; as explained by fig. 3d. plate 1st. in which A C B represent a level line, A E an inclined plane, whose perpendicular line or line of the earth's attraction B E, being to the line A E as one to four, points out that a power acting in the direction A E, against a body sliding
down

down the inclined plane, (friction apart,) need be but as one to four to it's weight, in order to resist it's motion ; and the same proportion holds in respect to every other degree of inclination ; for as C D is to D A, so should the power acting parallel to A D be in a like proportion, to hinder motion in a body perfectly smooth resting on D A, and acted on by gravity.

If the power exceed this proportion, as well as the friction, (which even the best polished surfaces are liable to,) then will it overcome the attraction of gravity, and force the sledge up the inclined plane. But the difficulty of exerting a power equal to that, of moving great weights up steep ascents, being great, and exceedingly encreased by the friction of such carriages, it has occasioned the application of wheels to them, as well to lessen the friction, as to overcome occasional obstacles, which in

many cases, it would not only be difficult for a sledge to be moved over, but which would be altogether impassable by any power applied in the common line of traction, any otherwise than by violently removing it.



S E C T I O N IV.

IT has been before observed, that the addition of wheels to carriages was intended to lessen the friction, and to overcome occasional obstacles more easily ; that it does both in a great degree, when properly applied, will appear from the following considerations.

A carriage such as a sledge sliding over a plane, suffers a friction or rubbing of it's parts against the plane, equal to the distance through which it moves ; but if an axle be applied to it, whose

whose circumference shall be six inches, and on that, wheels be placed whose circumference shall be eighteen feet, it is evident, that in moving the carriage eighteen feet over the plane, the wheels will make but one revolution ; and as there is no sliding of parts between the plane and the wheels but a mere change of surface, by one part of the latter rising, and the other descending nearly perpendicular to the former, no friction will take place there, the whole being transferr'd to the nave acting on the axle, which nave having made but the same one revolution as the outer circumference of the wheel, there has been but a sliding of parts equal to the circumference of the hole in the nave, which if it fitted the axle, would be but six inches ; consequently the friction is lessened, as one to thirty six, besides the advantage gained of confining it to so small a surface, whereby, the parts are more easily kept smooth, and fitted to each other, and substances applied and retain'd

tain'd to lessen the remaining friction.

Thus far the desired purpose is answered, and (the encreased weight of the wheel aside,) the lessening the friction will ever be in the same proportion, that the diameter or the circumference of the hole in the nave, bears to that of the whole wheel.

In respect to the next desideratum, which is that of overcoming occasional obstacles, as I shall endeavour to prove, that a wheel in such cases acts as a mechanical power, it will be quite necessary, previously to consider the principles, and laws whereby such powers are determined ; which being particular, as well as general, (all the different powers being but different combinations, of the inclined plane and the lever,) and the former having been before treated of sufficiently for our present purpose : the latter only remains to be understood.

S E C T I O N



S E C T I O N V.

A lever is a bar, some part or point of which, bears on or against a fixed body, having forces applied to it at different distances from it's bearing part, which is called it's fulcrum. Hence the lever is of three kinds ; the first, when the fulcrum is between the two acting powers, in which case if the lever be straight, they must act in the same direction ; the second is when both powers are on the same side of the fulcrum, and in that case must act in a direction opposite to each other.

Of the first sort are steelyards, rudders and tillers of ships, hammers, when used in drawing nails &c. Of the second are cutting knives. Also a ladder when raised by the exertion of a man under it, and its lower end confined, is considered.

considered as a third sort, being different from the cutting knife &c; for as the fulcrum in them is at one end, the power at the other, and the resistance between them; so in the other, the fulcrum is at one end, the weight or resistance at the other, and the power between both.

In every kind, the different forces required to ballance each other, are in exact proportion to their respective distances from the fulcrum; provided the action of the forces be applied at right angles with the lever, or rather with a line drawn from the fulcrum, to that part of the arms of the lever, where the power or resistance are applied, whether the arms of the lever be crooked or not; as in plate 1st. fig. 4th. which represents the most simple of the first sort of levers, F it's fulcrum.

Now as the point A is three times as far as the point B from the fulcrum, it will take a
weight

weight acting from B at right angles to the arm of the bar or lever, three times as heavy as at A to ballance it ; but being put in motion, the end A must descend three times the space thro' which, it raises B ; and so with the rest, fig. 5th, 6th, and 7th, plate 1st, observing this difference, that where the lever is crooked, a pulley must be used to give the power acting by the earth's attraction, a direction at right angles to the arm of the lever, on which it's relative distance from the fulcrum should be measured ; for should it act obliquely, part of it's effort would be lost in the proportion shewn in fig. 8th. plate 1st.

LET A B represent a lever supported on the fulcrum F ; the arm F B being but half the arm A F, one pound weight acting on the point A at right angles to that arm, will support two pounds weight at B, but if instead of a straight arm, it were crooked at the fulcrum, and
D lengthen'd

lengthen'd so as to rise to 50, then would the weight A act obliquely on it ; and altho' that arm would be much more than three times the arm F B, it would act with no more power on the lever, than the arm A F, which is but twice as long as F B, and so of the rest in proportion ; therefore, to calculate the effect of powers thus acting on the arms of a lever, it will be necessary to reduce the action to an imaginary line at right angles to it, on which to measure the distance from the fulcrum, and this method will hold good in every kind of lever and under every circumstance.



S E C T I O N VI.

HA V I N G thus explain'd the manner, in which friction is lessen'd by the application of wheels

wheels to carriages, and laid down the nature and doctrine of levers ; it remains to apply the latter, to prove that wheels under particular situations, act as, and are really the same as levers.

To illustrate this, let the circle O, T, A, G, L, plate 2d, fig. 1st. represent a wheel of four feet diameter, plac'd on the level P Q, and oppos'd in it's progress on that line, by the perpendicular obstacle O, ³ 7 100 inches in height : The line of traction being parallel to the plane as C T, in which direction a power is to be applied to raise the wheel with its load over the obstacle.

Now the effort being applied to the carriage, is communicated to the wheel, at the nave which touches the axle ; this point therefore represents the part of the lever, to which the power is applied, and is the point C in the figure ; and as the turning point is on the obstacle, that

D :

part

part of the wheel which touches it, will be the fulcrum of the lever ; that arm of the lever to which the power is applied, will be represented by the line or spoke, C O ; and as the upright spoke C L is in the line which bears the whole weight from the axle, and in which it is to be lifted ; therefore, is that part of the circumference of the wheel, which is between the fulcrum, and the upright spoke bearing on it, the arm of the lever which is to lift the weight ; and as in this case, neither the power nor the weight act at right angles to their respective arms of the lever, we must recur to the doctrine and rule laid down in page 26 where the effect of powers acting obliquely on levers is treated of, before we can compare the weight, to the power required to lift it over the obstacle ; and this is done by reducing the arms to imaginary lines, drawn from the fulcrum to the lines of action of the power and weight ; then will O M represent the arm of the lever's power, and

O

Fig. 2 Plates

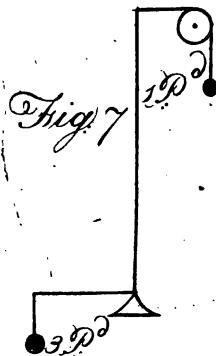
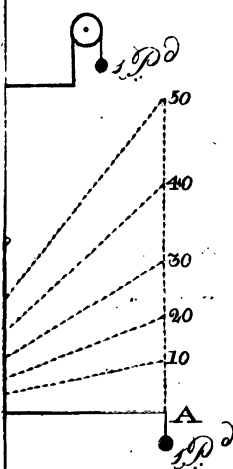
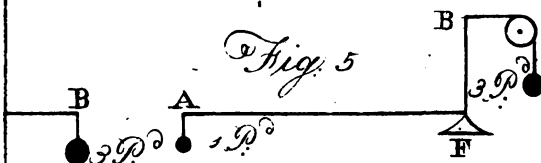
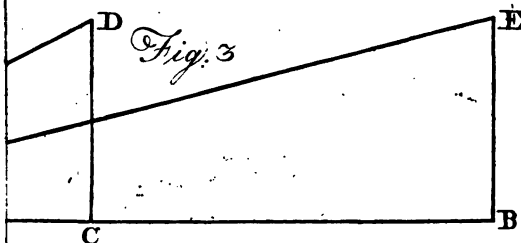
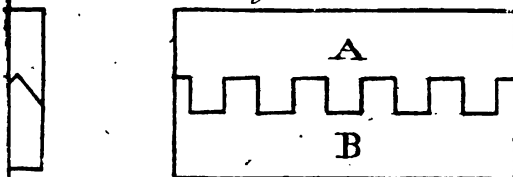


Fig. 7

ON that of it's weight ; and as the length of OM is to that of ON, so is the proportion required to the weight, to ballance it on the obstacle, when rising over it ; and as in this case the arms are equal, it is plain the power and weight must be so too.

EVERY perpendicular obstacle therefore, exceeding this proportion to the diameter of the wheel, which is as 7, 100³ to 48, will require a power acting on a line parallel to the plane, greater than the weight to be lifted ; and every obstacle of such form as with it's top to touch the wheel bearing a less proportion, will be nearly overcome by a power less than the weight Ex : plate 2d. fig. 2d. let the circle represent as before, a wheel of four feet diameter, to be moved on the plane PQ, and an obstacle be applied of twelve inches height : then will the real lever be represented by the lines L, O, C, and the
imaginary

imaginary one by M, O, N , by which we are to calculate the power ; for as the arm M, O , is to ON , so must the power acting in the direction CT from the axle be, which as before said is greater than the weight— And by the same rule, if an obstacle be presented to the wheel, as in fig. 1st. plate 3d. being but three inches, then will it require such a power to ballance the weight, as the arm M, O , is to the arm O, N ; consequently, the power required in this case, is less than the weight, and it will ever be in this proportion, while the line of traction remains the same ; but should that alter, so will the proportion, for instance, let the line of traction in the last mentioned figure be raised to the direction C, S , which is at right angles to the arm C, O , then will C, O , be the imaginary as well as real arm ; and consequently, so much will be gain'd, by thus altering the direction of the power, as the length of C, O , exceeds that of M, O .

FROM

From the preceding doctrine I hope, it will be clearly seen, that wheels in overcoming obstacles act as levers; but that they do so in proportion to their size, not having been so fully proved, it may be proper to consider the effect of a less wheel than before delineated, acting against an obstacle equally high with that laid down in fig. 1st. plate 2d.

Let the circle, plate 3d. fig. 2d, represent a wheel of two feet diameter, and the obstacle ³ 7, 100 inches; then will the lines C, O, L, as before, be the true lever, and M, O, N, the imaginary one, which (as the power must be to the weight as the line N, O, is to O, M, and which is more than double,) shews the great advantage of large over small wheels; for it was before proved, that half that power would nearly raise an equal weight over such an obstacle, applied in the same line of traction with

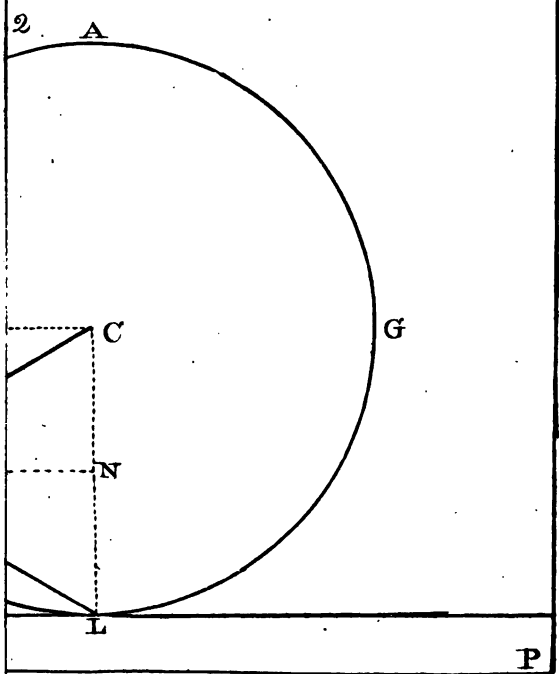
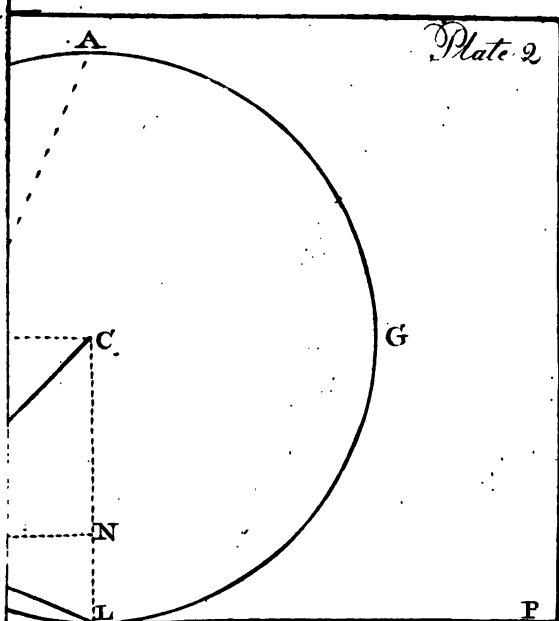
a wheel of double the diameter of that last laid down.

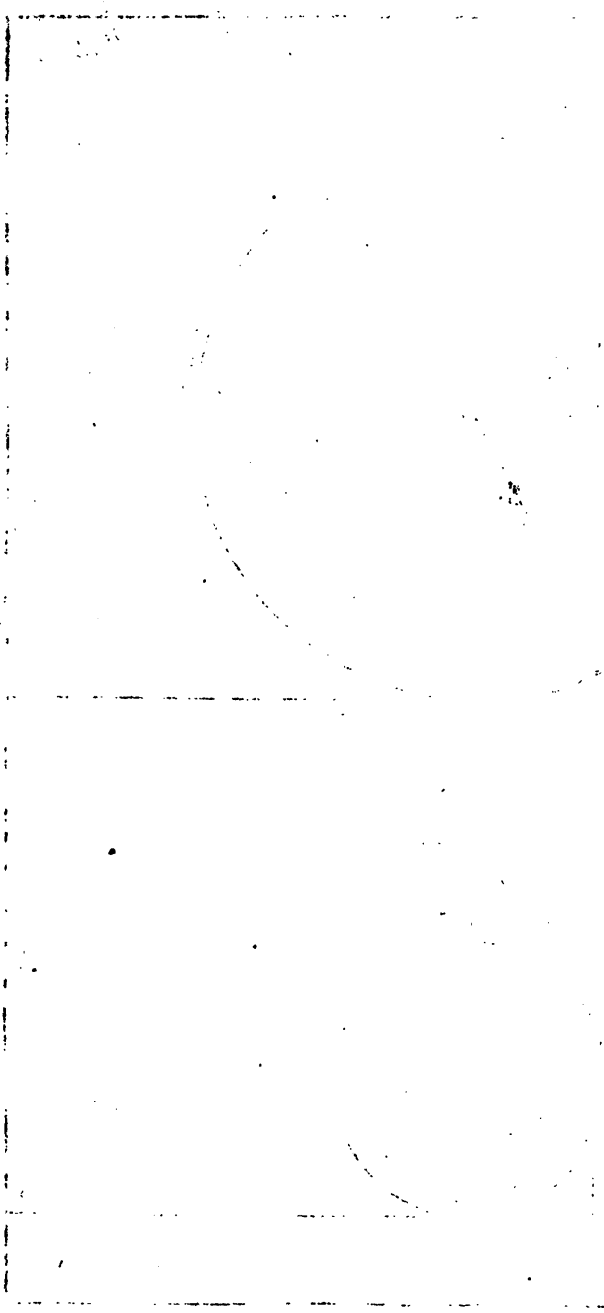


S E C T I O N VII.

TH U S far we have been considering the nature of wheels in overcoming obstacles by them, when the line of traction is parallel, (or nearly so) to the plane on which the obstacle lies, ‡ we now come to treat of the action of wheels when ascending inclined planes, and when

‡ It should be here remarked, that in every case, when a wheel acts as a mechanical power, it is governed by a law general to all of them, which is, that what is gain'd in power is lost in time, hence tho' a wheel of a certain diameter might be rais'd over an obstacle double the height, that a less wheel could be raised over with the same power, yet that power must be exerted twice as long to effect it, and so in proportion.





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when the line of traction is kept parallel to their ascent; and in this case we shall find, that notwithstanding they act as levers, and their power in raising a load up an ascent, may be calculated exactly by the same rule as before laid down; yet, in this case the action of the weight will increase with that of the power gain'd by the increased size of the wheel, which size therefore will be of no other consequence, than by lessening the friction, as it does in wheels passing over level planes.

To illustrate this, observe fig. 1st. plate 4th. in which, the larger circle represents a wheel of four feet diameter, and the lesser, one of two feet, ascending the inclined plane L, M, by powers applied in the directions G, T, and E; S, parallel to the elevation of the ascent, which is 45 degrees from the plane L; then will you find, that, (by describing the lever as before directed,) notwithstanding the power arm of the

E

lever

lever in the large wheel, be twice as long as that of the small, yet, as the arm to which the weight tends, is encreased in the same proportion, no advantage will be gain'd by it's superior size, other than as before was said in respect to the friction ; nor will the proportionate powers of the wheels be alter'd by the lines of traction being varied ; for while these are kept parallel to each other, their relative powers will be found to be equal ; and the reason is obvious, because in wheels ascending or descending regular inclined planes of any elevation, the fulcrum of the lever contain'd in them, is determin'd by that part of the wheel which touches the plane, and which will ever be of the same proportionate height, both in a large and small wheel ; but it is not so, in respect to the fulcrum mark'd out on a wheel by perpendicular or irregular obstacles ; for then it will depend on the height of such obstacle, which will fix the fulcrum of the lever form'd, a certain height

height on the wheel, without any regard to it's diameter. Consequently, the larger the wheel the greater it's advantage, and the more so, as an obstacle may be of such a height, as to render it impossible for any power to cause the wheel to surmount it; and which ever happens when an obstacle rises perpendicular from the plane, as high as that part of the wheel, which is cut by a line drawn from the axle parallel to the line of traction.

Ex: LET the circle, fig. 2d. plate 4th. describe a wheel on the plane L, V; if an obstacle be presented as high as R C, and the line of traction be C F, then will it be impossible by any force applied in that direction, to cause the wheel to surmount it: if the line of traction were in the direction C E, a power as much exceeding the weight as C H exceeds C B, (the two arms of the lever form'd) would nearly lift it over the obstacle: but no power would

lift it over R, B, except the line of traction were rais'd; which if it were to C D, then would a power exceeding the weight as much as C B exceeds B A, nearly raise it over, but no power in that line would raise it, if the obstacle were as high as R A, and so on.



S E C T I O N VIII.

A F T E R having shewn in the first part of this treatise, the principle on which bodies descend by their gravity on inclined planes, and pointed out the method of calculating the power necessary

Plate 4

Fig. 1

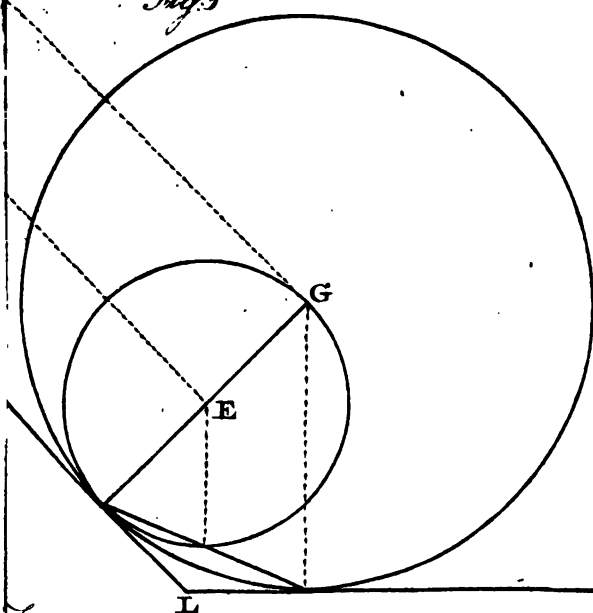
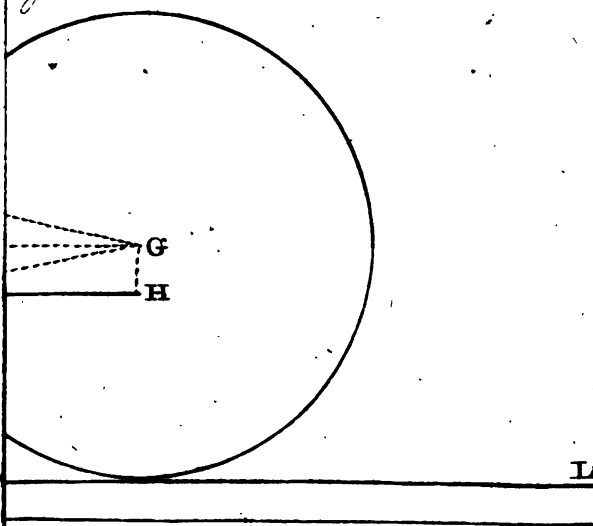
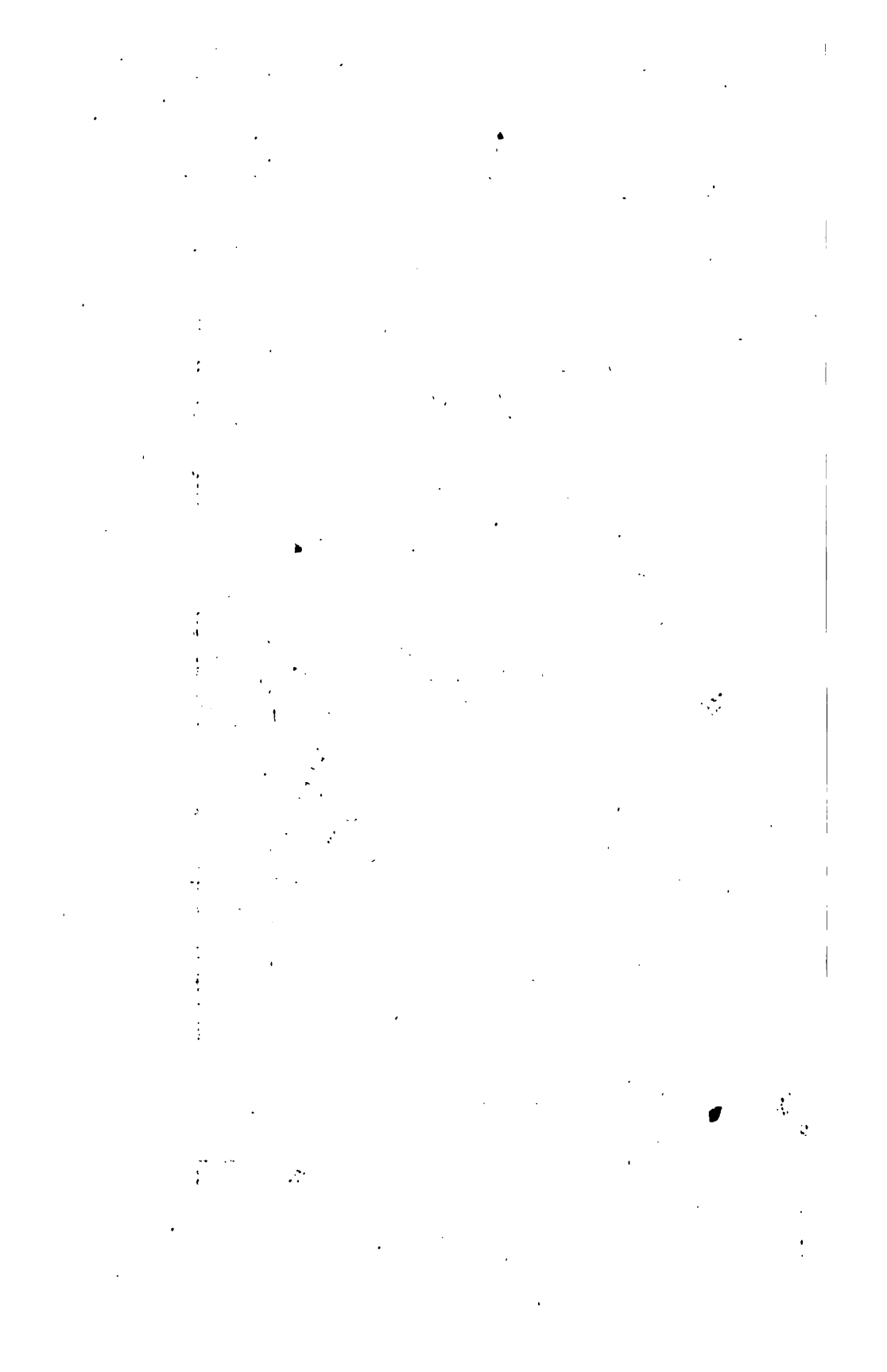


Fig. 2





necessary to be exerted, to hinder their descent, or move them in a contrary direction, it will be no small proof of the doctrine since laid down of the action of wheels, as levers, to shew that agreeably to the laws of mechanical powers, they exactly correspond in every case, where both occur ; which is ever so, when the surface over which the wheel is to move, happens to be a regular inclination to or from the natural level.

For an illustration of which, observe fig. 1st. plate 5th. in which, the circle is the representation of a wheel, to be rais'd up the inclin'd plane I, P, being 45 degrees from the level line L, the line of traction C R being describ'd, C, F, D will be the real lever, and C, F, L, the imaginary one, by which to calculate the power ; for as C, F, is to F, L, so must be the power to the weight to ballance it on the plane I, P.

Now

Now, if instead of calculating by the action of the wheels, we consider it as a body to be raised up the inclined plane, and leave friction out of the account, we must take a portion of the plane to work from ; I S for instance, then will the perpendicular be S T, and as was said in page 18 a power acting parallel to the ascent, to ballance the weight acting by gravity, must be as the line I S, is to the line S T, which will be found exactly the same proportion as that by the lever-scheme, and corroborates that doctrine, as well as the position, that wheels act not as mechanical powers in proportion to their size, on level ground or regular ascents, but that they act altogether so, in overcoming occasional obstacles.—

To enumerate the deductions to be drawn from the preceding arguments with a view to apply them to practice, the following observations occur.

FIRST

FIRST, That to generate motion in a carriage without wheels on level ground, nothing more is necessary, than to exert a power sufficient to overcome the friction of the parts, which are to slide over each other ; which friction will ever be in a compound proportionate ratio of the weight, and the form, size and strength of the roughnesses which occasion the friction.

SECONDLY, That by the application of wheels to such a carriage, the friction is as much lessen'd, as the circumference of the wheels exceeds that of the holes in their naves, in which their axles work.

THIRDLY, That in the draught of a carriage without wheels up a regular plain ascent, there is not only the friction to be overcome by the power applied, but there must also be exerted sufficient, to lift such a proportion of the weight of the carriage &c. and itself, as the perpendicular

cular ascent of any part of the ascending plane bears to that portion of the plane.

FOURTHLY, That if wheels of any size be applied to the carriage so circumstanced, they only advantage the effect of the power applied, by lessening the friction; for altho' they really act as levers, yet as each arm of the lever encreases in length, with the encrease of the size of the wheels, their power will be no greater, than as the inclined plane may be considered, as a mechanical power to raise the carriage &c. up the ascent.

FIFTHLY, That in raising carriages over perpendicular obstacles, large wheels have the advantage over small ones (by acting as levers) nearly in proportion to their respective sizes.

SIXTHLY, That the line of traction of any carriage, should if possible, be ever directly parallel

parallel to that, in which the carriage is to be moved; (for then will the arm of the lever to which the power applies, be the longest possible in the wheel) that is, in moving over planes, it should be parallel to the plane, and in surmounting an obstacle, it should be perpendicular to the spoke of the wheel, which points to the obstacle.

But as it may not be easily contrived, so to vary the line under different circumstances, it will be found better to fix it, at some medium between that which mostly occurs, and that which requires the greatest exertion, when it happens; or in other words, somewhere between a level line suited to plain ground, and regular ascents, and a rising line perpendicular to the spoke of the wheel, which points to the obstacle, it is most likely to meet with; and the more attention should be paid to the last, as all wheels but more especially small ones, are liable

to sink into the ground, over which they may pass, and thereby cause a constant obstacle to their progress.

AND here it may not be improper to observe, that the line of traction is not an imaginary line, drawn from that part of the animal to which the traces or chains are attach'd, to the axle of the wheel ; but the real direction of the traces, to whatever part of the carriage they are fastened ; for it is evident that in whatever direction, the effort be applied to one part of the carriage, it will be communicated to the other parts in the same direction, being all fastened together and forming one body.

SECTION



S E C T I O N IX.

WE have been hitherto considering the whole weight of carriages, as bearing perpendicularly on the axles of their wheels ; but, as this is not practically the case in chairs, carts, and other carriages having but two wheels, it will be necessary to treat particularly of their construction ; and if we have a view alone to that, which is best in regard to their traction under different circumstances, I shall endeavour to shew that it is necessary their centers, (or rather transverse lines) of gravity be brought, as near the axle of the wheel as possible ; and if we have a view to their safety, the nearer that center is to the ground the better.

To understand this, it is necessary to know,

F₂

that

that the center of gravity of any body is that point of it, which being suspended, all the other parts of it will continue at rest, in whatever situation it be placed ; as in a wheel, or circle of any equiponderous substance, the line or point of gravity is thro', and in the center, by which the circle is described.

In a square, whether superficial, or solid, that point which is equidistant from it's sides, is the center of gravity ; for it is evident, that a line which represents the earth's attraction, (or the gravity of the body) being drawn thro' this center, it can be turned in no direction about it, but as much matter will be on one side of that line, as on the other ; as fig. 2d. and 3d, plate 5th. will point out ; in which, C is the center of each, round which if they be turned, as much will be on one side of the dotted line, which is that of their gravity, as on the other, let their situation be what it may.

Just

Just so, has every figure however irregular, such a center of gravity ; tho' it may be somewhat more difficult to determine it's place exactly.

If therefore any body be suspended by a transverse line passing thro' it, either below, or above that point, the equipoise of the body will only be preserved, while it is kept in one erect position ; for should the suspension be below, and the body turned forwards, (as is the case with two wheel'd carriages descending hills,) then will the greater part of the weight be thrown before the axle, and must partly be borne up by the animal drawing it ; and if ascending the same proportion will be thrown backwards, and tend to lift the animal, whose weight can alone preserve the ballance (by it's action on the shafts ;) which will not only be a pain and hindrance to it, but encrease the friction on the nave and axle, as it encreases the weight on them, just so much as that
of

of the animal tends to preserve the balance.

If the body be suspended above the center of gravity, then will the disadvantage be equal, but the effect will be reversed as to ascending and descending hills ; that is, whilst the body is attached to shafts fixed to the animal ; but should the weight be hung under the axle independent of the shafts, then will it always hang perpendicular to the center of gravity, and be the same in effect, as if it hung immediately by it.

It may not be thought ill placed here to treat of a position, generally, but erroneously asserted ; which is in respect to the disadvantages, I have just said, carriages suspended above or below their center of gravity are liable to ; namely, that these are increas'd in proportion to the height of the wheels ; because, the hinder part of the load in ascending a hill, being thrown back, will overhang that part of a large wheel, which

which touches the ascending plane, much more than that of a smaller one.

BUT the fallacy of this reasoning will appear, if we consider that all the disadvantage in either case is express'd by the weight, which from it's action on the axle, tends to lift the animal, and that this must be the same whether the wheels be high or low, the figs. in plate 6th. will explain; fig. 1st. represents a carriage on two wheels of four feet diameter, ascending a plane of 35 degrees elevation from the level L, E; fig. 2d. is one, whose wheels are six feet diameter, circumstanced exactly the same as the former, C the center and S, P, the line of gravity, A, R, the line of suspension; in each, the body is thrown so far back by it's ascending position, that the space G, S and A, R is taken from before the line of gravity, and added to the part behind it; consequently, a weight of the animal, equal to the weight of double that space, must

must be exerted on the shaft to ballance it ; but as was befor said, this is exactly the same in both the cases, which the figures represent, altho' the wheels are very different in size, and the point T is so much the farther, from where the line of gravity falls in the second figure, than in the first ; yet it occasions no other difference, than was pointed out in the case of wheels acting as levers, in which it was shewn, that under such circumstances their *power* was equal.

As it is inconvenient for many reasons, to place the center of gravity, in the body of a carriage low enough in respect to it's wheels : the best mode to remedy the defect, is to form two lines of bearing by the application of three or four instead of two wheels ; and to place those at such distance from each other, that the line of gravity may always fall between the two lines of bearing in every situation, to which the carriage may be liable.

For

Plate 5

Fig. 1

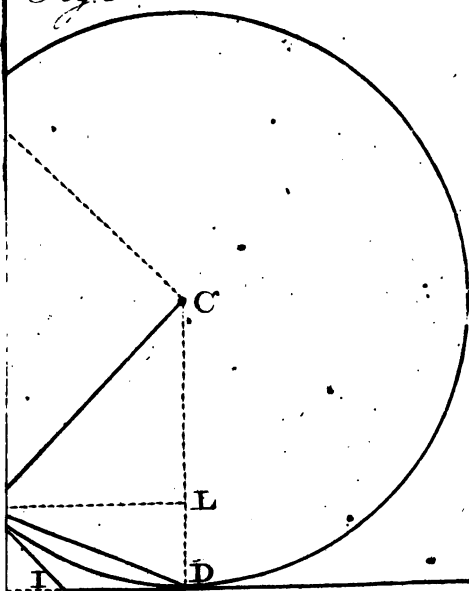
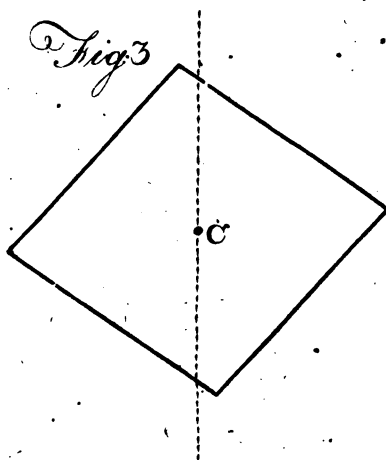


Fig. 3



For fig. 3d. plate 6th. will shew that if the body A be placed on four wheels, whose axles are at B and C, then will it be entirely supported between them, (but mostly by C) even tho' the carriage were ascending a hill equal in elevation to H I, which is fifty degrees from the level L E : and in this case, no exertion is requisite in the animal drawing it, to ballance the carriage in it's bearings ; whereas, had it been supported by the axle of two wheels only at S, then would it's far greater part be thrown behind the center of suspension, and require a power equal to double the weight of the space between the lines F G, to preserve the equilibrium.

From hence it is demonstrable, that the further the distance, the axles of three or four wheel'd carriages are from each other, the less liable will the line of gravity be, to fall on, or beyond either of them ; but as this distance en-

creases the difficulty of turning a carriage, a medium is, and ought to be observed therein.



S E C T I O N X.

WH A T has been said in respect of keeping the line of gravity within one of the points of suspension, as necessary to a carriage in ascending or descending hills, will pretty generally apply as to it's safety from overturning, on roads out of level, or uneven, in their transverse direction, with this difference, that as wheels are not movable on an axle in that direction, we must consider the points of suspension
of

NOTE : The term suspension is used instead of support, which is more proper, in order not to confound with a variety of terms.

of the whole, as plac'd in those points, where they touch the road, for let fig. 1st. plate 7th. represent a cross section of a carriage supported by two wheels ; C it's center of gravity ; this carriage being on level ground the whole weight of C is supported equally by the two points A B, but place it on ground transversely unlevel, as in fig. 2d. then will the center of gravity, and consequently the whole weight nearly bear on the point B, as much falling on one side of it, as on the other ; with this great disadvantage to the lower wheel, B D, that it's spokes will not receive the weight perpendicularly, but somewhat across them, and thereby lessen their strenght, at a time when it is necessary they should be the strongest, having more than their share, if not all of the weight to bear.

It is further evident, that if their points of bearing were removed to a greater distance from the carriage, it's safety would be encreased ; as the

G 2

road

road must recline more in proportion, before the line of gravity would reach them on either side.

To effect this, as well as to remedy the disadvantage before mentioned, of the lower spokes of wheels being thrown out of their perpendicular direction, when most requisite it should be preserved, the dishing of wheels was invented ; and this is done, by setting their spokes into the nave in such manner, as to decline every way from the carriage ; whereby, they bear on the road as represented by the dotted lines in the figure last referred to, and effect the purposes before described. But as almost every advantage gain'd by such contrivances, is attended by some disadvantage, so is it with this ; for by thus forming the wheels, the space the carriage takes up on the road is greater, which makes it more unmanageable ; and by the spokes not bearing perpendicularly when on plain

Plate 6

Fig. 2

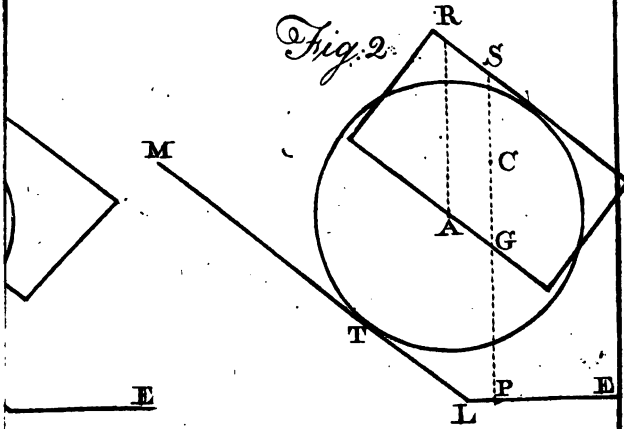
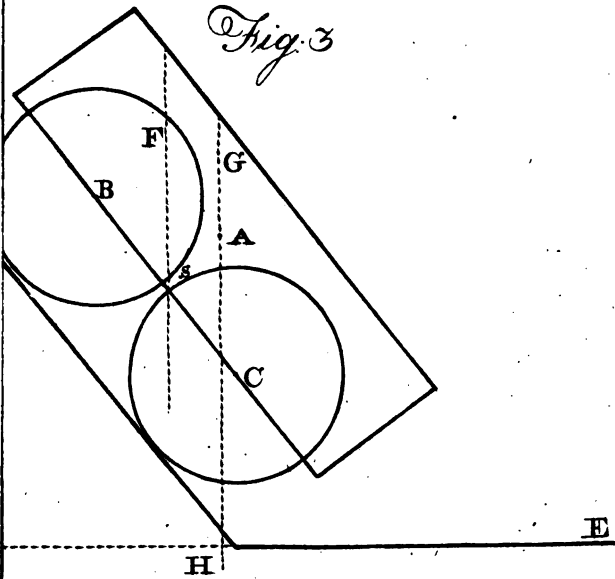


Fig. 3



plain ground, they are then less strong, and which is worse, they cannot bear equal and plain between the nave and axle ; for the more they dish, the greater will be the friction on the upper part of the inner, and under part of the outer bearing of the axle : as fig. 3d. plate 7th. shews more clearly ; for if the wheels there describ'd, be so placed with their outer circumference erect, they would fall towards each other, were they not supported by the axle passing thro' them ; because all their weight lies on that side of their bearing points ; the weight of which axle, and consequently, that of all the carriage and it's load bearing on it, would entcrease that tendency in the wheels, and cause the outer part of each to press upwards and the inner downwards against the axle.

It was perhaps to obviate this last disadvantage, that the bending the ends of axles downwards obtain'd in practice ; but the least consideration

deration will demonstrate, that the lower spokes of wheels are thereby thrown erect, and every advantage of dishing them is lost, while it doubtless encreases the breadth from wheel to wheel aloft.

AND yet worse is the practice of bending axle ends forwards, for by so doing the wheels are thrown out of that parallel direction they should ever stand in, on the line of their progress; and it tends to draw them towards the carriage; in both cases occasioning a considerable friction between the nave, and the shoulder of the axle, and in the latter, some degree of it between the wheel and the ground; for the wheels, placed in the situation they must be in, if the axle be bent forwards would soon draw together by their rolling on the ground, if they were not kept asunder by the shoulders on the axles; and therefore in every revolution, there must be a rubbing sideways on the ground.

THE

THE only reasons, I am aware of, that can be justly assigned for this construction, are, that the axle is thereby strengthened, and that all the bendings and wearings, that, and the nave are liable to, from the weight placed on them, and from accidental causes, tend to bring them to that direction they should stand in ; but surely, these do not warrant this prevailing practice, in opposition to the great disadvantages attending it.



S E C T I O N X I.

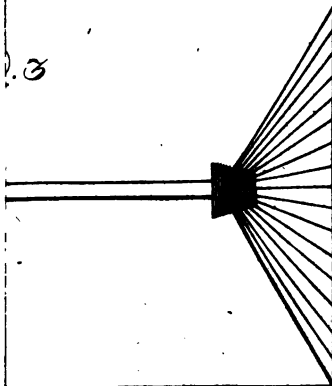
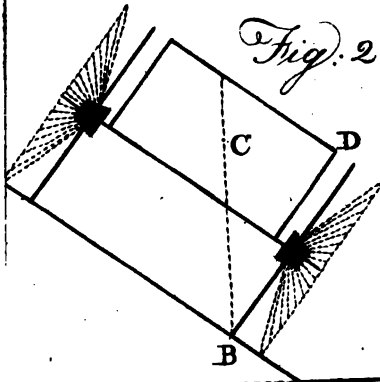
TH U S far the action of wheels as generally applied to carriages is treated of, I have now to point out the use of extraordinary applications to encrease their effects ; and this may be done, either,

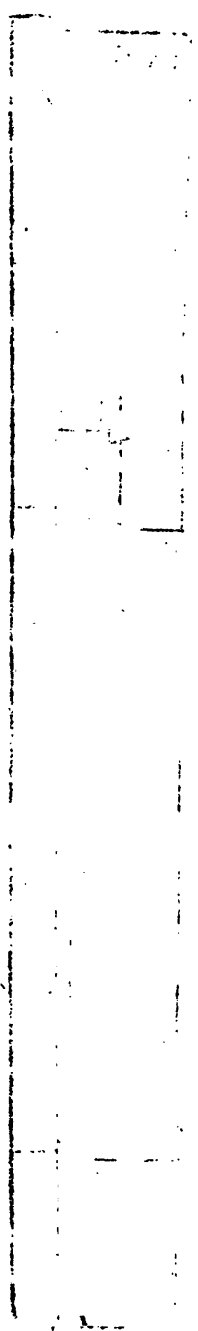
either, by lengthening the power arm of the lever contain'd in the wheel, (whose diameter shall yet remain the same,) or, by lessening the friction of the nave and axle; thro' the application of friction-wheels or rollers.

THE first of these, can in it's nature be but a temporary expedient, but is often used when an obstacle presents it self to the wheel of a carriage; which, tho' it need be surmounted, yet it cannot be done by the power then applied in the common mode of traction, in which, it's application is at the axle; but may by transferring the action of that power, from the center to the upper part of the periphery of the wheel; by which means the power arm of the lever contain'd in the wheel is nearly doubled, as is explain'd by the fig. 1st. plate 2d. for, if the power be applied to the wheel at A, then instead of C O being the arm of the lever, it would be represented by the dotted line A, O, which being

Plate 7

Fig. 2





ing nearly double C O, the same will be their comparative powers.

Now it may be asked, why is not a general advantage taken of this application, by the chain, (whereby the animal draws the carriage) being wound round the wheel, so that the point of traction may be thereby always kept at A ? I reply, with that general mechanical theorem, that as the power is by this means encreased, time is lost, or in other words, the animal from which the power is derived, must go twice as fast as the carriage, to effect it's motion by this application ; for altho' the chain if so wound round the wheel, could only unwind from it a length, equal to the distance it passes over the ground, yet as the wheel is in a progressive motion as well as the animal, consequently the latter must pass over not only the ground which the former does, but also a space equal to the

H length

length of the chain for unwinding, which is just twice as much, and it therefore confines the use of this application to very short distances.



S E C T I O N XII.

WE are not so bounded in respect to the use of friction wheels and rollers, which not acting as mechanical powers, but being solely contrivances to lessen the friction of the touching surfaces when in motion, are not subject to the above mechanical law; and may therefore be applied ad infinitum, without further injury or loss than such as arise from their incumbrance.

The best application of the first of these to carriage wheels, is to fix the wheel and axle to each other in such manner, that they may turn together;

ther ; then, must two friction wheels a little overlapping each other, be fixed on each side of the body of the carriage, so that it may bear on the axle in the interfection of the wheels ; as in fig. 1st. plate 8th. in which, A, B, C, D is the body of a cart, the larger circle, the periphery of one of it's wheels fasten'd on the axle E ; the circumference of each friction-wheel three feet, that of their axles three inches ; now, as the great wheel revolves by the motion of the carriage there will be no rubbing of parts between the axle and the friction-wheels, but all will be transferred to their axles ; for the same reason as was shewn, why the friction in a common case was transferred from the ground, and outer circumference of the wheel rolling on it, to it's nave and axle.

EVERY revolution of the great wheel, in which it passes over eighteen feet of ground, the axle of that wheel moves the lesser ones round one

sixth of their circle ; consequently, their axles are moved thro' the same proportion of their circumference, and just so much friction is caused ; which being but equal to half an inch, is lessen'd in the proportion of that measure to eighteen feet, which is 432 times in the whole, or twelve times less by the addition of friction-wheels to what it would be without them. For notwithstanding the axles on both sides are in motion, yet the calculation must be as if one only moved, for the more wheels there are which receive the bearing, the more will the weight, and consequently the friction be divided.

It will be objected to the fixing the wheels, and axles together as first directed, that they are thereby hindered from moving with different velocities, as is requisite, when ever the carriage is moving out of a right line : but should such friction-wheels be adopted, the objection may be easily

easily removed ; by leaving the wheel loose on their axles ; by which means they will be at liberty to move there, with different velocities when requisite, and at the same time have the advantage of the friction-wheels always as to one wheel, and generally as to both.

BUT the use of this contrivance seems likely to be entirely superseded, by an invention of rollers lately completed by Mr. GARNETT of BRISTOL ; these for their general applicableness to all wheel work, their simplicity, strength, compactness, cheapness and little liability to injury, bid fair to rival any invention that can possibly be applied to answer their purpose.— It is true, the part invented by him was in it self very small, and simple, but as all was inapplicable without that part, it is the same, as if all were his own construction ; and he has therefore very deservedly obtained a patent for the sole vending them.

I do not know, that I could do justice to the whole of his machinery, should I attempt it, (nor am I certain, that he has not, or does not intend publishing on the use of them,) but their general principle is this.

BETWEEN the axle and nave of any wheel-work, is left a space to be fill'd up by solid equal rollers nearly touching each other ; these have axles, which are inserted into a circular ring at either end, whereby their relative distances to each other are preserved, and they are kept parallel by these circular rings being fastened together by means of wires, (which pass between the rollers) and are rivitted to them.

To understand the effect of this machinery clearly, we must proceed in the same line we have before observed, and consider the action of rollers simply between parallel surfaces, under
different

different circumstances as to projection and motion.

FIRST as to plane surfaces with a roller between them, it will be found that if one be fixed, and the other in motion parallel to it's surface, it will move forward a roller placed between them, but with half the degree of it's own motion ; because of the reaction of the stationary plane, which causes the roller to roll back on the moving one, as much as that causes it to move forward on the other : for example, see fig. 2d. plate 8th. if C D be a fixed surface, and A B a movable one, with a roller E between them, and B be moved forward to G, it will cause the roller to move on to F, which is but half the distance A B has gone, because it has rolled in a retrograde direction as far against the surface B A, as it has forward on the other ; and that solely on account of the opposition it met with from C D ; for if it did not touch that surface,
and

and was by any other means attach'd to A B, it would be carried with it, thro' equal space without any rolling motion ; this being understood, it will be clear, that if a roller be placed between two circular surfaces, such as the axle and nave of a wheel, and the wheel be turned round, then the roller, (which if it were not for it's rolling motion against the axle, would be carried round with the nave,) will, if left to it's proper action roll on the axle ; but as by so doing, it will also roll with a retrograde motion against the nave, equal to it's rolling forward on the axle ; the nave in order to carry it quite round must be turned so much beyond a whole revolution, as is equal on it's inner circumference, to the whole circumference of the axle.

EXAMPLE, let A, B, C, D, fig. 3d. plate 8th. represent the nave of the wheel E, whose inner circumference is eighteen inches, the axle of which

which we will suppose so small, that it may be considered as a point : F G two rollers between them closely fitted ; if then the wheel be turn'd the rollers will be carried with it round the point P ; for as we consider it but as a point, there can be neither rolling nor friction against it, but if the axle be of a sensible size, for instance one inch circumference ; then must each roller roll round by the motion of the nave against it, and the resistance of the axle on the opposite side ; but to effect this, it will roll in a retrograde direction against the nave ; therefore, that must go as far beyond a revolution, as is equal to the circumference of the axle upon it, before the roller can go once round the axle, which in this case is ¹ 18 by the same reasoning as used in treating of rollers between straight surfaces.

SHOULD the axle be nine inches in circumference, and that of the inner part of the nave re-

main as before ; then must the wheel revolve once and half, to carry the roller once round the axle, and so on in the same proportion : but as the circumference of an axle must be ever less, than the inner part of a nave turning on it with rollers between ; it never can amount to two whole revolutions of the wheel round the axle, however near it may come to it, for the segment of no circle can be a right line.

FROM these considerations it is evident, that, if several rollers be placed round between the nave and axle, which ever way the wheel be turned, there will be no rubbing of parts, but only a rolling of the rollers ; and that if they be all of one size and nicely fitted, they will keep their respective distances, and answer the purpose of destroying friction.

THIS has been long known ; but as by accidental causes such loose rollers were liable to approach

proach each other, and by touching occasion great friction, their use was neglected, 'till Mr. GARNETT remedied this defect, by applying an axle to each roller, and inserting them into the circular bands before mentioned ; as in fig. 4th. plate 8th. in which A, B, C, D, represent a cog of metal to be inserted into a sheave or nave of any wheel work ; E the axle, I rollers between them of solid metal, having axes inserted into the circle of brass, which passes over their center ; and there being one such other ring at the other end, and both revitted together by bolts passing between the rollers, they are by this means kept seperate and parallel.

It is true, that by this contrivance some friction takes place, between the axles of the rollers, and their sockets in the brass rings ; yet as the quantity of friction has been shewn to depend chiefly on the force, by which the rubbing sur-

faces are press'd together, and as in this case there is but the slight pressure occasion'd by the tendency, the rollers may have to approach each other by accidental causes, (no weight of the wheel or carriage affecting them,) the friction can be but very trifling, indeed so little, as not to raise the least objection to this excellent machinery, which with the improvements and additions of it's inventor to adapt them to carriage wheels, will in my opinion make their way to general use.

F I N I S.



